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Working for Clean Water
An Information Program for Advisory Groups

Cost-Effectiveness Analysis

Instructor Guide

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This project is dedicated to the memory of Susan A. Cole.

Cost-Effectiveness Analysis

The Federal Water Pollution Control Act Amendments of 1972, Public Law 92-500, is a landmark piece of environmental legislation. In addition to setting a national goal of zero pollution discharge, it provides the basis for managing the nation's water quality. The U.S. Environmental Protection Agency (EPA) has established rules and regulations to carry out the provisions of the Act, including the use of cost-effectiveness analysis in the facility planning process. Cost-effectiveness analysis permits the selection of a plan from among alternative proposals. It is an attempt to integrate all important considerations early in the planning process.

Upon the completion of this session the participant should:

- Know the scope of cost-effectiveness analysis
- Be familiar with the assessment procedures
- Understand the role of citizens in analysis of the alternatives.

Required Materials

☐ Set of slides and cassette tape for the audiovisual presentation, "Cost-Effectiveness Analysis"

☐ Slide projector, cassette-tape player, and screen

☐ Set of transparencies with overhead projector and chalkboard or flip chart with easel for guided discussion

☐ Copy of the handbook "Cost-Effectiveness Analysis" for each participant

☐ Copy of the handouts for each participant. They include: Problem Background (1 page), Selected Nonmonetary Effects (1 page), Discount Tables (2 pages), and Cost-Effectiveness Analysis Accounts Sheet, Present Worth Analysis (3 pages)

☐ Electronic calculators (optional).

best copy available

Important Notes

1. Several instructional options exist. The instructor may:

   a. Show the slide-tape program without substantive discussion

   b. The audiovisual presentation may precede a problem exercise

   c. The audiovisual presentation and the problem exercise may be covered <u>together</u>. In this arrangement, the slide-tape program is stopped several times at musical interludes. At these intervals, various aspects of the exercise are discussed. The arrangement of alternating the slide-tape program and the exercise should reinforce the cost-effectiveness analysis principles.

2. In preparing for the presentation, preview the slide-tape script. This program features a case study. Principles of cost-effectiveness analysis are not introduced until relatively late in the program.

3. Charts are used to facilitate discussion. It may be necessary for the instructor or an assistant to prepare these charts prior to the presentation. The contents for the charts are listed in the Appendix.

4. Charts made by the instructor should contain only information that is essential to the discussion. Charts with many words or numbers are difficult to read. However, transparencies of numerical tables may be needed for discussion of the present worth analysis.

5. Small electronic calculators can greatly speed up the computations.

6. Do not hand out the answers to the problem exercise (i.e., present worth analysis answer sheets) until the end of the session. These answer sheets are separate from the background information and worksheets.

7. Some persons have an aversion to economics or mathematics. In dealing with these problems, the instructor must be able to present the material with minimum technical jargon, and maximum practical experiences and anecdotes.

8. Encourage the participants to take notes on the discussion. Worksheets are provided. Note-taking will reinforce the learning experience.

Suggested Activities

Introductory Comments	5 minutes
Audiovisual Presentation	16 minutes
Guided Discussion	34 minutes
Closing Remarks	5 minutes
TOTAL TIME	60 minutes

Introductory Comments (5 minutes)

1. Give a little history of the use of cost-effectiveness analysis in water quality planning. Mention the impetus of Public Law 92-500 and The Clean Water Act amendments of 1977.

2. Discuss briefly the procedure's role, advantages, and disadvantages (e.g., bias towards quantified monetary costs).

3. Caution the participants that they are advisors rahter than analysts who will perform the studies. The analysis can involve very technical considerations. The objective of this session is to get the participants familiar enough with cost-effectivenss to provide meaningful advice, rather than to develop technical competence.

Audiovisual Presentation - Guided Discussion (50 minutes)

Note: The A/V presentation may be played in its entirety after discussion of the first five items OR used step-wise at appropriate points throughout.

See item 6 which follows.

1. Discuss the scope of cost-effectiveness analysis. The EPA has published guidelines (Federal Register, Vol. 43, No. 188. September 27, 1978) for comparing wastewater management alternatives. The topics include effectiveness in meeting goals, monetary costs, financial costs, environmental effects, social and economic effects, technical reliability, implementation feasibility, and public acceptance.

Use chart 1 on Elements of Cost-Effectiveness Analysis.

2. In the detailed cost-effectiveness evluation, additional considerations and procedures must be taken into account. They are:

- Total present worth calculations for monetary costs — a procedure for estimating costs to a point-in-time
- Flow reduction approaches such as water conservation programs (watersaving devices, pricing policies, regulations, and public education)

• Staging of collection and treatment facilities.

Use chart 2 on Wastewater Management Options.

3. The formation of a facilities plan is not limited to these topics for cost-effectiveness analysis. Other considerations are required by the law and EPA regulations in developing alternatives. They include considerations of:

• Treatment and discharge of the effluent by conventional methods

• Innovative and alternative systems, especially land treatment and wastewater reuse.

Cost-effectiveness analysis provides an opportunity to see that all of these considerations have been included in the planning effort.

Use chart 3 on Water Quality Planning.

4. The participant may question where all these considerations fit into the planning process. Cost-effectiveness analysis primarily involves the latter steps of the process in which the alternatives are formed, evaluated, and displayed for the selection of a plan.

5. Much information has been introduced. Briefly recap the main points, as: Cost-effectiveness analysis is a procedure for comparing alternatives. Monetary costs and nonmonetary factors such as environmental effects and implementation feasibility provide the basis for the evaluation.

Ask the participants to keep these points in mind as the case study and exercise are covered.

Script is in Appendix.

6. Start the slide-tape program, "Cost-Effectiveness Analysis." It documents the case study featured in the citizen handbook.

At this point either show the audiovisual without interruption OR stop it at intervals to discuss the cost-effectiveness problem. The musical intervals in the presentation provide appropriate starting and stopping points.

7. The development and preliminary screening of alternatives are not a central focus of cost-effectiveness analysis. However, they are important because data is gathered, and assumptions are made at this phase which establish the boundaries for the analysis.

8. Briefly explore the roles that advisory groups have in this part of the planning process, such as:

Important!

- Identifying problems and need areas
- Having knowledge of local values
- Questioning analysis assumptions and procedures

Pointing out innovative and alternative technologies, and multiple use options.

9. Restart the audiovisual presentation if using the second instructional approach. Stop the tape at the next musical interval.

10. The evaluation of monetary costs is quite important in cost-effectiveness analysis.

Discuss the types of monetary costs that should be included in an analysis, for example: capital, mitigation, opportunity, operations and management (O&M) and replacement costs.

Which ones are apparently missing in the problem exercise?

Opportunity costs associated with a lost recreation site.

11. Present worth analysis is used to put all monetary costs on a comparative basis by discounting future costs back to the present. This procedure works like the interest rate computation in reverse.

Briefly discuss what is needed for a present worth analysis, such as:

- Disaggregated costs and benefits such as revenues from the sale of waste nutrients
- Facility life span
- Water Resource Council interest and discount rate
- Estimated salvage value of the facilities at end of the project period.

12. Pass out the handout materials to the participants. Tell them to look over the background for the cost-effectiveness problem. At this point do not pass out the answer sheets to the present worth analysis problem.

Use handouts on Problem Background, and Discount Tables.

13. Costs and revenues presented on the problem background handout have to be calculated for each year for each alternative. These separate discounted costs and revenues are then aggregated into the following equation which gives the total present worth (PW) of different alternatives:

Use chart 4 on Present Worth Analysis.

> Total PW = initial capital costs + PW of future costs - PW of revenues and salvage.

Go through one or two sample present worth calculations in the problem exercise. Have the participants follow along with their worksheets and discount tables. Simple, straightforward calculations are suggested. These calculations should demonstrate the use of the discount tables. Sample calculations could include upgrading costs and O&M costs.

Use handout on Present Worth Analysis.

Hand out the answer sheets to the present worth analysis problem.

Important!

Based upon this limited exercise, discuss how cost-effectiveness calculations can go wrong.

- Use of improper table discount rate and life span
- Costs of monetary benefits attributed to wrong years
- Inaccurate assessment of the magnitude of impacts
- Avoidance of some costs such as opportunity costs
- Mechanical computation errors.

14. Mention the role of advisory groups in evaluating monetary costs, such as identifying costs and benefits, and checking assumptions and procedures of the analysis.

15. Start the audiovisual presentation again if using the second approach. Stop the tape at the next musical interval.

Use chart 5 on Nonmonetary Factors.

16. Nonmonetary effects are another important area in evaluating wastewater management alternatives. These additional factors include:

- Environmental effects, including economic and social considerations
- Resource use and energy consumption
- Reliability and feasibility
- Implementation capability

• Public acceptability.

17. Not only are these considerations difficult to compare quantitatively, but they are also very complex. Refer participants to a list of approximately 30 environmental factors given in the citizen handbook.

Discuss briefly the nonmonetary impacts of the problem exercise, including:

Use handout on Nonmonetary Effects.

• Aquatic enrichment, possibly eutrophication

• Decreased stream diversity

• Aesthetic losses and recreational losses

• Land owners inconvenienced by sewer construction, traffic disruption, and noise

• Flexibility of staged-growth alternative

• Temporary loss of wildlife habitat along sewer.

18. If using the second instructional option, start the slide-tape program again and play it until the end.

19. The last step in cost-effectiveness analysis is the display of all information for the comparative evaluation of alternatives. An accounts sheet is often the best way to organize the diverse categories of information.

Using the handout provided, set up a display of all the information for cost-effectiveness analysis of the alternatives given in the problem exercise.

Use handout on Cost-Effectiveness Analysis Accounts Sheet.

Please note that this analysis is abbreviated and incomplete, and is used only for illustrative purposes.

20. Advisory groups can assist in this last part of the analysis procedure. They can:

Important!

• Assist in identifying tradeoffs, especially the composite effects of alternatives

• Evaluate all factors together.

Closing Remarks (5 minutes)

1. Briefly reiterate the main points about cost-effectiveness analysis that were discussed at the end of the citizen handbook. They are:

- Cost-effectiveness analysis permits the systematic comparison of wastewater management alternatives. The costs of achieving comparable goals using different alternatives are compared.

- It should result in an integrated documentation of both monetary and nonmonetary factors — a display that clearly shows the tradeoffs among the alternatives.

- The main components of cost-effectiveness analysis are monetary costs, nonmonetary factors such as environment and social costs, and implementation considerations such as system reliability.

- Cost-effectiveness analysis is part of a five-step planning sequence. It is most useful in the latter steps of the process — the evaluation of alternatives, and the selection of a plan.

- Costs and benefits of several alternatives are compared at the same point in time through present worth analysis.

- Advisory groups can give valuable assistance at several places in analysis process.

2. Answer any remaining questions.

Selected Resources

Guidance for Preparing a Facility Plan. EPA-430/9-76-015. Washington, DC: Office of Water Program Operations, Municipal Construction Division, U.S. Environmental Protection Agency, May 1975. 32 pp. with references and appendices. Order No. MCD-46.

This publication briefly discusses the facility planning process. Featured are the considerations at each planning step such as cost-effectiveness analysis, the format of plans, and the relationship of facility plans to other water quality management and planning programs. More detailed instructions are given in the January 1974 version of the same document. This document is available from the General Services Administration, Centralized Mailing List Service, Building 41, Denver Federal Center, Denver, CO 80225. Give the order number and the document title when placing orders.

University of Wisconsin-Extension, Department of Engineering and Applied Science. Facility Planning for Wastewater Treatment Works. FP201 Second Series, seminar - workshop manual, "Cost-Effectiveness Analysis" workshop. Atlanta, GA: Region IV, U.S.Environmental Protection Agency, November 28 - December 1, 1978. pp. B1-B10 and E1-E13.

This manual is used during an intensive four-day series of seminars and workshops on current issues in facility planning. Topics include: cost-effectiveness analysis, innovative and alternative systems; nonmonetary assessment; statutory and regulatory requisites; EPA policy on the review of waste treatment alternatives; small and individual systems; project management; public participation; land treatment, pretreatment; sludge disposal; sewer system evaluation; plan development. Order from Professor John Quigley, University of Wisconsin-Extension, 432 North Lake Street, Madison, WI 53706.

Schmidt, C.J. and D.E. Ross. Cost-Effectiveness Analysis of Municipal Wastewater Reuse. WPD-4-76-01. Washington, DC: Water Planning Division, U.S. Environmental Protection Agency, April 1975. 116 pp. with 5 appendices.

This book pertains specifically to alternatives which reuse wastewater, but it contains a chapter on cost-effectiveness analysis. This section gives the basic procedures for the technique, the EPA cost-effectiveness guidelines, and formats for present worth calculations. This document is available from Library Services, U.S. Environmental Protection Agency, Research Triangle Park, NC 27711.

Conclusions Wastewater Management Study of the Central Pennypack. Publication Number 53. Harrisburg, PA: Bureau of Water Quality Management, Department of Environmental Resources, November 1977. 78 pp.

The analysis of three wastewater management alternatives is summarized. The key issues, the cost-effectiveness evaluation, and an implementation schedule are given. Appendices make up over half of the document, and contain consultant reports, letters, and cost calculations. The position and rationale of the Department of Environmental Resources are featured. Copies are available free (as long as they last) from the Pennsylvania Department of Environmental Resources, Bureau of Water Quality Management, Division of Water Quality, P.O. Box 263, Harrisburg, PA 17120

Construction Grants Program. Municipal Wastewater Treatment Works. Appendix A: Cost-Effectiveness Analysis. Federal Register. Vol. 43, No. 188. September 27, 1978.

Copies of the Federal Register can be obtained through local libraries.

Appendix

A. Contents of charts for use by the instructor in the suggested activities. These pages may be used to make transparencies, or the contents may be copied onto flip charts.

1. Elements of Cost-Effectiveness Analysis
2. Wastewater Management
3. Water Quality Planning
4. Present Worth Analysis
5. Nonmonetary Factors

B. Handouts for use by the instructor in the guided discussion. Copies will need to be made for each participant.

1. Problem Background
2. Discount Tables (2 pages)
3. Present Worth Analysis (3 pages)
4. Selected Nonmonetary Effects
5. Cost-Effectiveness Analysis Accounts Sheet

C. Copy of the script for the slide-tape program, "Cost-Effectiveness Analysis."

Elements of Cost-Effectiveness Analysis

Goal effectiveness
Monetary costs
Economic costs
Social costs
Environmental effects
System reliability
Implementation feasibility
Public acceptance

Wastewater Management

Conventional treatment and disposal
Alternative and innovative systems

Water Quality Planning

1. Determine problems
2. Define solution objectives
3. Develop alternatives
4. Evaluate options
5. Select plan

Present Worth Analysis

Total Present Worth (PW)	=	Initial Capital Costs	+	PW of Future Costs	−	PW of Revenues

Nonmonetary Factors

Environmental effects
Resource use
Reliability and flexibility
Implementation capability
Public acceptability

Problem Background

In the screening process, the wastewater management options have been narrowed down to two alternatives with the same total treatment capacity and the same quality of effluent. However, they differ as to costs, salvage values, construction stages, and nonmonetary aspects.

Both alternatives are conventional treatment systems, consisting of a secondary activated sludge process and gravity sewers. Unfortunately, the site for the treatment plant is a wooded area that is presently used as a boy scout camp. A shallow, slow-moving stream is to receive the effluent.

Monetary Costs

	Alternative A	Alternative B
Capacity (million gallons per day)	10 mgd	10 mgd
Linear flow increase over 20 years	2 to 10 mgd	2 to 10 mgd
Planning period (years)	20	20
Initial plant cost	$3,000,000	$2,000,000 (@ 5 mgd)
Salvage value at end of 20 years	$0	$750,000
Upgrading cost at year 10 to 10 mgd	$0	$1,500,000
Constant annual O & M cost, years 1 to 10	$126,000	$84,000
years 11 to 20	$126,000	$165,000
Variable annual O & M cost, years 1 to 10 linear increase	$0 to 68,000 over 20 years	$0 to 29,000
years 11 to 20 linear increase		$0 to 29,000
Interest rate	7%	7%
Mitigation costs		
Capital - year 1	$113,000	$65,000
year 10	$0	88,000

Present Value $1/(1+i)^n$

Periods	Rate i				
n	.06 (6%)	.065 (6½%)	.07 (7%)	.075 (7½%)	.08 (8%)
1	.9433 9623	.9389 6714	.9345 7944	.9302 3256	.9259 2593
2	.8899 9644	.8816 5928	.8734 3873	.8653 3261	.8573 4882
3	.8396 1928	.8278 4909	.8162 9788	.8049 6057	.7938 3224
4	.7920 9366	.7773 2309	.7628 9521	.7488 0053	.7350 2985
5	.7472 5817	.7298 8084	.7129 8618	.6965 5863	.6805 8320
6	.7049 6054	.6853 3412	.6663 4222	.6479 0152	.6301 6964
7	.6650 5711	.6435 0021	.6227 4974	.6027 5490	.5834 9040
8	.6274 1237	.6042 3119	.5820 0910	.5607 0223	.5402 6888
9	.5918 9846	.5673 5323	.5439 3374	.5215 8347	.5002 4897
10	.5583 9478	.5327 2604	.5083 4929	.4851 9393	.4631 9349
11	.5267 8753	.5002 1224	.4750 9280	.4513 4319	.4288 8286
12	.4969 9timo	.4696 8285	.4440 1196	.4198 5413	.3971 1376
13	.4688 3902	.4410 1676	.4149 6445	.3905 6198	.3676 9792
14	.4423 0096	.4141 0025	.3878 1724	.3633 1347	.3404 6104
15	.4172 6506	.3888 2652	.3624 4602	.3379 6602	.3152 4170
16	.3936 4628	.3650 9533	.3387 3460	.3143 8699	.2918 9047
17	.3713 6442	.3428 1251	.3165 7439	.2924 5302	.2702 6895
18	.3503 4379	.3218 8969	.2958 6392	.2720 4932	.2502 4903
19	.3305 1301	.3022 4384	.2765 0833	.2530 6913	.2317 1206
20	.3118 0473	.2837 9703	.2584 1900	.2354 1315	.2145 4821
21	.2941 5540	.2664 7608	.2415 1309	.2189 8897	.1986 5575
22	.2775 0510	.2502 1228	.2257 1317	.2037 1067	.1839 4051
23	.2617 9726	.2349 4111	.2109 4688	.1894 9830	.1703 1528
24	.2469 7855	.2206 0198	.1971 4662	.1762 7749	.1576 9934
25	.2329 9863	.2071 3801	.1842 4918	.1639 7906	.1460 1790
26	.2198 1003	.1944 9579	.1721 9549	.1525 3866	.1352 0176
27	.2073 6795	.1826 2515	.1609 3037	.1418 9643	.1251 8682
28	.1956 3014	.1714 7902	.1504 0221	.1319 9668	.1159 1372
29	.1845 5674	.1610 1316	.1405 6282	.1227 8761	.1073 2752
30	.1741 1013	.1511 8607	.1313 6712	.1142 2103	.0993 7733
31	.1642 5484	.1419 5875	.1227 7301	.1062 5212	.0920 1605
32	.1549 5740	.1332 9460	.1147 4113	.0988 3918	.0852 0005
33	.1461 8622	.1251 5925	.1072 3470	.0919 4343	.0788 8893
34	.1379 1153	.1175 2042	.1002 1934	.0855 2877	.0730 4531
35	.1301 0522	.1103 4781	.0936 6294	.0795 6164	.0676 3454
36	.1227 4077	.1036 1297	.0875 3546	.0740 1083	.0626 2458
37	.1157 9318	.0972 8917	.0818 0884	.0688 4729	.0579 8572
38	.1092 3885	.0913 5134	.0764 5686	.0640 4399	.0536 9048
39	.1030 5552	.0857 7590	.0714 5501	.0595 7580	.0497 1341
40	.0972 2210	.0805 4075	.0667 8038	.0554 1935	.0460 3093
41	.0917 1905	.0756 2512	.0624 1157	.0515 5288	.0426 2123
42	.0865 2740	.0710 0950	.0583 2857	.0479 5617	.0394 6411
43	.0816 2962	.0666 7559	.0545 1268	.0446 1039	.0365 4084
44	.0770 0908	.0626 0619	.0509 4643	.0414 9804	.0338 3411
45	.0726 5007	.0587 8515	.0476 1349	.0386 0283	.0313 2788
46	.0685 3781	.0551 9733	.0444 9859	.0359 0961	.0290 0730
47	.0646 5831	.0518 2848	.0415 8747	.0334 0428	.0268 5861
48	.0609 9840	.0486 6524	.0388 6679	.0310 7375	.0248 6908
49	.0575 4566	.0456 9506	.0363 2410	.0289 0582	.0230 2693
50	.0542 8836	.0429 0616	.0339 4776	.0268 8913	.0213 2123

Present Value of Annuity $[1-(1+i)^{-n}]/i$

Periods	Rate i				
n	.06 (6%)	.065 (6½%)	.07 (7%)	.075 (7½%)	.08 (8%)
1	0.9433 9623	0.9389 6714	0.9345 7944	0.9302 3256	0.9259 2593
2	1.8333 9267	1.8206 2042	1.8080 1817	1.7955 6517	1.7832 6475
3	2.6730 1195	2.6484 7551	2.6243 1604	2.6006 2574	2.5770 9099
4	3.4651 0561	3.4257 9800	3.3872 1126	3.3493 2627	3.3121 2084
5	4.2123 6379	4.1556 7944	4.1001 9744	4.0458 8400	3.9927 1004
6	4.9173 2433	4.8410 1356	4.7665 3966	4.6938 4642	4.6228 7966
7	5.5823 8144	5.4845 1977	5.3892 8940	5.2966 0132	5.2063 7006
8	6.2097 9381	6.0887 8096	5.9712 9851	5.8573 0355	5.7466 3891
9	6.8016 9227	6.6561 0419	6.5152 3225	6.3788 8703	6.2468 8791
10	7.3600 8705	7.1888 3022	7.0235 8154	6.8640 8096	6.7100 8140
11	7.8868 7458	7.6890 4246	7.4986 7434	7.3154 2415	7.1389 6426
12	8.3838 4394	8.1587 2532	7.9426 8630	7.7352 7827	7.5360 7802
13	8.8526 8296	8.5997 4208	8.3576 5074	8.1258 4026	7.9037 7594
14	9.2949 8303	9.0138 4233	8.7454 6799	8.4891 5373	8.2442 3698
15	9.7122 4809	9.4026 6885	9.1079 1401	8.8271 1975	8.5594 7869
16	10.1058 9527	9.7677 6418	9.4466 4860	9.1415 0674	8.8513 0619
17	10.4772 5969	10.1105 7670	9.7632 2299	9.4339 5976	9.1216 3811
18	10.8276 0348	10.4324 6638	10.0590 8691	9.7060 0908	9.3718 8714
19	11.1581 1649	10.7347 1022	10.3355 9524	9.9590 7821	9.6035 9920
20	11.4699 2122	11.0185 0725	10.5940 1425	10.1944 9136	9.8181 4741
21	11.7640 7662	11.2849 8333	10.8355 2733	10.4134 8033	10.0168 0316
22	12.0415 8172	11.5351 9562	11.0611 4050	10.6171 9101	10.2007 4366
23	12.3033 7808	11.7701 3673	11.2721 8738	10.8066 8931	10.3710 5895
24	12.5503 5753	11.9907 3871	11.4693 3400	10.9829 6680	10.5287 5828
25	12.7833 5616	12.1978 7073	11.6535 8318	11.1469 4586	10.6747 7619
26	13.0031 6619	12.3923 7251	11.8257 7867	11.2994 8452	10.8099 7795
27	13.2105 3414	12.5749 9766	11.9867 0904	11.4413 8095	10.9351 6477
28	13.4061 6428	12.7464 7668	12.1371 1125	11.5733 7763	11.0510 7849
29	13.5907 2102	12.9074 8984	12.2776 7407	11.6961 6524	11.1584 0601
30	13.7648 3115	13.0586 7591	12.4090 4118	11.8103 8627	11.2577 8334
31	13.9290 8599	13.2006 3465	12.5318 1419	11.9166 3839	11.3497 9939
32	14.0840 4339	13.3339 2925	12.6465 5532	12.0154 7757	11.4349 9944
33	14.2302 2961	13.4590 8850	12.7537 9002	12.1074 2099	11.5138 8837
34	14.3681 4114	13.5766 0892	12.8540 0936	12.1929 4976	11.5869 3367
35	14.4982 4636	13.6869 5673	12.9476 7230	12.2725 1141	11.6545 6822
36	14.6209 8713	13.7905 6970	13.0352 0776	12.3465 2224	11.7171 9279
37	14.7367 8031	13.8878 5887	13.1170 1660	12.4153 6952	11.7751 7851
38	14.8460 1916	13.9792 1021	13.1934 7345	12.4794 1351	11.8288 6899
39	14.9490 7468	14.0649 8611	13.2649 2846	12.5389 8931	11.8785 8240
40	15.0462 0687	14.1455 2687	13.3317 0884	12.5944 0866	11.9246 1333
41	15.1380 1592	14.2211 5199	13.3941 2041	12.6459 6155	11.9672 3457
42	15.2245 4332	14.2921 6149	13.4524 4898	12.6939 1772	12.0066 9867
43	15.3061 7294	14.3588 3708	13.5069 6167	12.7385 2811	12.0432 3951
44	15.3831 8202	14.4214 4327	13.5579 0810	12.7800 2615	12.0770 7362
45	15.4558 3209	14.4802 2842	13.6055 2159	12.8186 2898	12.1084 0150
46	15.5243 6990	14.5354 2575	13.6500 2018	12.8545 3858	12.1374 0880
47	15.5890 2821	14.5872 5422	13.6916 0764	12.8879 4287	12.1642 6741
48	15.6500 2661	14.6359 1946	13.7304 7443	12.9190 1662	12.1891 3649
49	15.7075 7227	14.6816 1451	13.7667 9853	12.9479 2244	12.2121 6341
50	15.7618 6064	14.7245 2067	13.8007 4620	12.9748 1157	12.2334 8461

Source

Hodgman, Charles D., editor, C.R.C. Standard Mathematical Tables, 12th Edition Cleveland, OH: Chemical Rubber Publishing Company, 1959. pages 451 and 467.

Discount Tables (continued)

Present Value of Gradient Series

n	7%	8%	10%	12%	15%	20%	n
1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1
2	0.8734	0.8573	0.8264	0.7972	0.7561	0.6944	2
3	2.5060	2.4450	2.3291	2.2208	2.0712	1.8519	3
4	4.7947	4.6501	4.3781	4.1273	3.7864	3.2986	4
5	7.6467	7.3724	6.8618	6.3970	5.7751	4.9061	5
6	10.9784	10.5233	9.6842	8.9302	7.9368	6.5806	6
7	14.7149	14.0242	12.7631	11.6443	10.1924	8.2551	7
8	18.7889	17.8061	16.0287	14.4715	12.4807	9.8831	8
9	23.1404	21.8081	19.4215	17.3563	14.7548	11.4335	9
10	27.7156	25.9768	22.8913	20.2541	16.9795	12.8871	10
11	32.4665	30.2657	26.3963	23.1289	19.1289	14.2330	11
12	37.3506	34.6339	29.9012	25.9523	21.1849	15.4667	12
13	42.3302	39.0463	33.3772	28.7024	23.1352	16.5883	13
14	47.3718	43.4723	36.8005	31.3624	24.9725	17.6008	14
15	52.4461	47.8857	40.1520	33.9202	26.6930	18.5095	15
16	57.5271	52.2640	43.4164	36.3670	28.2960	19.3208	16
17	62.5923	56.5883	46.5820	38.6973	29.7828	20.0419	17
18	67.6220	60.8426	49.6396	40.9080	31.1565	20.6805	18
19	72.5991	65.0134	52.5827	42.9979	32.4213	21.2439	19
20	77.5091	69.0898	55.4069	44.9676	33.5822	21.7395	20
21	82.3393	73.0629	58.1095	46.8188	34.6448	22.1742	21
22	87.0793	76.9257	60.6893	48.5543	35.6150	22.5546	22
23	91.7201	80.6726	63.1462	50.1776	36.4988	22.8867	23
24	96.2545	84.2997	65.4813	51.6929	37.3023	23.1760	24
25	100.6765	87.8041	67.6964	53.1047	38.0314	23.4276	25
30	120.9718	103.4558	77.0766	58.7821	40.7526	24.2628	30
35	138.1353	116.0920	83.9872	62.6052	42.3587	24.6614	35
40	152.2928	126.0422	88.9526	65.1159	43.2830	24.8469	40
45	163.7559	133.7331	92.4545	66.7343	43.8051	24.9316	45
50	172.9051	139.5928	94.8889	67.7625	44.0958	24.9698	50

Source

Grant, Eugene L., W. Grant Ireson, Richard S. Leavenworth. Principles of Engineering Economy. Sixth Edition. New York, NY: The Ronald Press Company, 1972. pp. 606-607.

Present Worth Analysis

Alternative A

Step 1

Initial cost = $3,000,000

Step 2

To find the present worth of operating costs, it will be necessary to calculate separately the present worth of the constant costs and the variable costs.

a. Present worth of constant annual costs equals that cost times the uniform series present worth factor @ 7.0% for 20 years. Thus:

$126,000 (10.5940) = $1,335,000

b. Present worth of a variable cost increasing linearly is found by first finding the amount of increase per year. This amount is $68,000/20 years or $3,400 per year. This increase is known as a gradient series. This series times the correct gradient series present worth factor @ 7.0% for 20 years yields the present worth of the variable cost. Thus:

$3,400 (77.5091) = $ 264,000

Step 3

Mitigation costs are at the base year. No discounting is necessary.

$ 113,000

Step 4

Sum of numbers obtained in the steps above yields present worth:

initial cost =	$3,000,000
present worth of constant O&M costs =	1,335,000
present worth of variable O&M costs =	264,000
present worth of mitigation costs =	113,000
total present worth	$4,712,000

Step 5

As before, the present worth just derived times the capital recovery factor @ 7.0% for 20 years will yield the average annual equivalent cost. Thus:

$4,712,000 (.9439)= $ 444,800

which is the average annual equivalent cost of the plant for 20 years.

Alternative B

Step 1

initial cost= $2,000,000

Step 2

Calculate the present worth of the O&M costs as follows:

a. Present worth of constant annual cost years 1-10 equals given cost times uniform series present worth factors @ 7.0% for 10 years. Thus:

$84,000 (7.024)= $ 590,000

b. Present worth of the variable O&M costs years 1-10 equals the gradient series ($2,900) times the present worth factor of a gradient series @ 7.0% for 10 years. Thus:

$2,900 (27.7156)= $ 80,400

c. The present worth of the constant O&M costs year 11-20 are first calculated as in (a) above using the given cost for years 11-20. This, however, yields present worth in year 11 which must be converted to present worth in year 1. This is accomplished by multiplying the present worth (year 11) times the single payment present worth factor @ 7.0% for 10 years (.5083). Thus, present worth in year 1 equals:

$165,000 (7.024) (.5083)= $ 589,100

d. The present worth of the variable O&M costs years 11-20 are first calculated as in (b) above using the gradient series for years 11-20 which is $2,900. This yields the present worth in year 11 which again must be converted to present worth in year 1 by multiplying the present worth (year 11) times the single payment present worth factor @ 7.0% for 10 years (.5083). Thus:

$2,000 (27.7156) (.5083)= $ 40,900

Step 3

To determine the present worth of the upgrade cost which occurs at year 10, multiply the upgrade cost times the single payment present worth factors @ 7.0% for 10 years. Thus:

$1,500,000 (.5083)=	$ 763,000

Step 4

The present worth of the salvage value at the end of 20 years equals that value times the single payment present worth factor @ 7.0% for 20 years. Thus:

$750,000 (.2584)=	$ 194,000

Step 5

The mitigation of impacts is done in two stages; costs in year 10 must be discounted. Those in the base year are not discounted.

$65,000 + ($88,000 x .5083)=	$ 109,700

Step 6

The sums of the values obtained in Steps 1, 2, 3, and 5 minus the value obtained in Step 4 will equal the present worth of the plan. Thus:

initial cost=	$2,000,000
present worth of constant O&M year 1-10=	590,000
present worth of variable O&M year 1-10=	80,400
present worth of constant O&M year 11-20=	589,100
present worth of variable O&M year 11-20=	40,900
present worth of upgrade at year 10=	763,000
present worth of mitigation costs=	109,700
TOTAL	$4,173,100

Subtract from the total the present worth of salvage value

present worth of salvage value=	$ 194,000
total present worth=	$3,979,100

Step 7

As before, the present worth just derived times the capital inventory factor @7.0% for 20 years will yield the average annual equivalent cost. Thus:

$3,979,100 (.09439)=	$ 375,600

which is the average annual equivalent cost of the plant over 20 years.

Selected Nonmonetary Effects

1. Construction of the sewers will cause dust, noise, traffic disruption, and other inconveniences. The total magnitude, at least initially, should be less for the staged alternative. Social and secondary impacts such as development are not considered extensively in either alternative.

2. Aesthetic and recreational losses occur as the woodland is cut for the construction site, and the stream undergoes eutrophication. This impact would be reduced slightly with the staged alternative.

3. A decline in diversity of aquatic organisms would also accompany the eutrophication processes and construction activities. Full recovery from the construction effects may be delayed by the staged alternative.

4. Low stream flows will not dilute the effluent sufficiently. Flow augmentation with associated mitigative costs will be necessary. Except for timing, no significant differences seem to exist between the alternatives.

5. Temporary wildlife habitat destruction will occur along the sewer routes from construction activities. Depending upon the location of the interceptors, more losses may occur with the nonstaged alternative.

6. Since the two plans for the treatment plant use the same site and same disposal methods, no opportunity costs exist. However, the location of sewers through prime farmland in one alternative, but not the other one, could generate opportunity costs.

7. The staged alternative permits more growth flexibility compared with the other option.

Cost-Effectiveness Analysis Accounts Sheet

Factor	Evaluation	
	Alternative A	Alternative B
1. Water Quality Goals		
2. Monetary Costs		
A. System Outlay Costs		
B. Opportunity Costs		
3. Financial Costs		
4. Environmental Effects		
A. Hydrology		
B. Biology		
C. Air Quality		
D. Land		
E. Energy and Resource Use		
5. Social and Economic Changes		
A. Land Values		
B. Employment		
C. Dislocation		
D. Health		
E. Aesthetics		
6. Technical Reliability		
7. Implementation Feasibility		
8. Public Acceptability		

Audiovisual Script

COST-EFFECTIVENESS ANALYSIS

Slide Description	Narrative
1. Cassette Start	
2. Title: Cost-Effective Analysis	Music
3. Map of Pa. with arrow	Near the Southeast border of Pennsylvania is the large metropolitan area that takes in Philadelphia, Pa., Trenton, N.J., and Wilmington, Del. Within this area, a rapidly dwindling supply of open space and green areas--and the occurrence of water quality problems have in recent years been cause for much concern.
4. Closeup of map of area	At the heart of one particular wastewater management controversy is an area known as the Pennypack Watershed. It seems that the area along Pennypack Creek represents the only significant remaining green belt that is adjacent to Philadelphia. And to preserve this area and to deal with pollution problems,
5. Group of people at meeting	the three local municipalities and a private citizens group called the Pennypack Watershed Association got involved in an interesting wastewater management problem.
(Graphic) 6. List of alternatives	In the early 1970's, several alternative wastewater management proposals had been made; including: a spray irrigation system and an interceptor or pipeline leading to an existing wastewater treatment plant in Philadelphia. Well, --after the various alternative proposals were made, the problem became --
(Graphic) 7. Question mark over meeting	How to decide which of the alternatives was <u>best</u> for the area?

(Graphic) 8. Cost-Effectiveness Analysis	Cost-Effectiveness Analysis is the basis for the selection of alternatives.
(Graphic) 9. Facilities planning 6-step sequence 1. Determine problems 2. Define objectives 3. Develop alternatives 4. Evaluate alternatives 5. Select plan 6. Revise plan	Cost-Effectiveness Analysis is part of a 6-step planning sequence and is most useful in the latter steps of the process — the evaluation of alternatives, and the selection of a plan.
(Graphic) 10. Same as above, except number 1. Highlighted.	First, of course, water quality problems must be determined. Sometimes there is no present problem existing. But, water supply and wastewater treatment requirements must be considered for the future. For example, when it is projected that future wastewater treatment will exceed present capacity or if future treatment will fail to meet water quality standards, then the community does have a problem.
11. Photo of sedimentation	Water quality problems on the Pennypack that needed to be evaluated included: Sedimentation and debris,
12. Split scene: Flooding and dry stream beds	Flooding, Seasonally low stream flows, and
13. Photo of stream encroachment	Stream encroachment; developments were gradually getting closer and closer to the shoreline of the creek.
(Graphic) 14. Facilities planning: highlights 1. Determination of problems 2. Definition of objectives 3. Development of alternatives 4. Evaluation of alternatives 5. Plan selection 6. Revision of continued planning	If it has been determined that problems do exist, the next steps are to come up with some answers to the problems — and develop some alternative methods of dealing with the different water quality problems.

	(graphic)	
15.	List of alternatives	Some of the alternatives might include: 1) No facility needed--perhaps the problem could be dealt with in another way; 2) the improvement of existing facilities; 3) conventional collection and treatment systems; and, 4) alternative and innovative systems.
16.	Photo of advisory group Words:	At this point, in the early planning stages, advisory group input is very important.
17.	Phased Development Energy Requirements Multiple Use Opportunities	These and other considerations involve phased development, energy requirements, and multiple use opportunities.
18.	Graphic of brainstorming session	A good, old-fashioned brain-storming session is what's needed as a means of public participation. With input from all concerned citizens. Ideas, no matter how unconventional they might seem, should be discussed and considered. Other modes of public participation exist, and should be used.
19.	View of Pennypack area	In the Pennypack case, the following alternatives were explored:
20.	Split screen: spray irrigation/interceptor	Of all the alternatives, the two that looked most promising were spray irrigation and an interceptor. Both of these alternatives met water quality criteria and standards.
21.	Population graphic	Population projections were considered -- and although they varied slightly between consultants, the difference was not enough to effect wastewater flow estimates.
22.	Map of Pennypack	Another consideration was one of the legality of transferring wastes from one local government authority into another.

23. Advisory group picture

Other assumptions, considerations, alternatives--and, well --the whole general scope of the Pennypack study included:

(Graphic)

24. List

-construction site availability

-environmental effects

-social effects

-public acceptability

-implementation feasibility

-legality

-site suitability and capacity

--and last but certainly not least--

-economic costs.

MUSIC

(Graphic)

25. Facilities planning sequence: highlight

-Determination of problems
-Definition of objectives
-Development of alternatives
-Evaluation of alternatives

Cost-Effectiveness Analysis, although used throughout the planning process, is primarily involved in the evaluation of alternatives.

For each alternative various costs have to be determined. There are both monetary and nonmonetary costs.

26. Monetary Costs:

-present and future capital costs

-operation, maintenance and replacement costs

-opportunity costs

-mitigation costs

Monetary Costs examples might include present and future capital costs, operation, maintenance and replacement costs, opportunity costs such as the loss of potential income or resources , and mitigation costs.

(Graphic)

27. PRESENT WORTH ANALYSIS

Since amounts of money and timing of money outlays will vary among alternatives, it is necessary to express them on a common basis --and at the same point in time.

Present worth analysis has been developed for making such cost comparisons.

What information is needed to make a present worth analysis? How is the calculation done?

(Graphic)

28. Present Worth Discounting $\$ \times (1 + r)^{t}$

Cost — Interest or Discount Rate — Year

The present worth of future costs and benefits are estimated by a discounting procedure which, in essence, is the reverse of interest calculations. Hence, the discounting equation as shown, is merely the opposite of the interest calculation equation. In both instances, the only information needed is the cost, the interest or discount rate, and the year in which the cost occurs.

(Graphic)

29. Total = Initial Capital Costs

\+

PW of Future Costs

\-

PW of Revenues & Salvage Values

Worth (PW)

Such costs are calculated on a year-by-year basis, and are aggregated to give the total present worth of each alternative.

(Graphic)

30. Same as above with present worth highlighted

If all costs, monetary and nonmonetary, are similar and treatment efficiencies are comparable, the project with the LOWEST PRESENT WORTH must be selected to qualify for federal cost-sharing grants.

Music

31. Photo
Ducks

32. Photo
decaying wood

In the case of the Pennypack, the consultants did not agree on monetary costs.

As resolved by DER, the following cost estimates were made:

33.	Bar graph Capital, operating and management costs	The spray irrigation alternative had higher capital, operation and management, and replacement costs: About 1/3 higher, than the interceptor option.
34.	Bar graph Mitigation Costs	Both alternatives would have adverse effects on stream flows — the costs for lessening these adverse effects are called mitigation costs, and they would be about 3 times higher for the interceptor.
35.	Advisory group meeting photo	Situations that will need mitigation are commonly overlooked and advisory groups can be of special assistance in identifying such possible costs and pointing them out to the agency or consultant.
36.	(Graphic) List of costs	In the Pennypack case, it turned out that the interceptor, at first, appeared slightly less expensive than the spray irrigation but that was without consideration of the 9 million dollar opportunity cost
37.	(Graphic) Same as above with opportunity cost highlighted	that should be charged against the interceptor alternative. Overall, spray irrigation was more cost-effective.
38.	Photos split screen House and field/geese by stream	Other factors, such as energy use, reliability and flexibility, and environmental impacts must be included in the cost-effectiveness analysis. Music

(Graphic)

39. Nonmonetary evaluation

If economic costs were all that mattered, the alternative with lowest present worth would be chosen; however, nonmonetary factors are just as important.

(Graphic)

40. List

These factors are:

-environmental effects (including social impacts)

-reliability and flexibility

-implementation capability

-resource use and energy consumption, and,

-public acceptance

(Graphic)

41. Same as above but with environmental highlighted

The environmental assessment is done concurrently with other studies in the facilities planning process.

(Photo split screen)

42. Stream bottom sampling & groundwater sampling

An inventory of environmental conditions should be compiled. It will provide a base against which predicted environmental changes may be evaluated--sampling stream bottom organisms, and taking groundwater samples are examples of evaluation techniques that can be included in the inventory.

(Graphic)

43. Direct and indirect effects

Both direct and indirect environmental effects may be revealed in the analysis.

44. Picture of treatment plant

Direct effects relate directly to the location, construction and operation of the project.

Examples of direct beneficial effects include recharged groundwaters from land treatment.

45. Photo of sewer overflow

Negative effects may include erosion along sewer lines, overflows from sewer manholes, odors, loss of open space, noise, and air pollution from incinerated sludge.

(Graphic)
46. With indirect highlighted

Indirect effects are the indirect changes that are induced by a project.

PHOTO:
47. development near stream

These include changes in population, economic growth, and land use such as development around sewer interceptors.

Split screen:
48. spray/interceptor photo

In the Pennypack example, regarding environmental effects, spray irrigation was much more advantageous compared to the interceptor alternative.

49. Stream photo

Spray irrigation would increase streamflow, while the interceptor would reduce streamflow.

Spray irrigation would permit more kinds of aquatic organisms to live.

50. Photo of deer

Spray would stimulate less development, thus disturbing fewer wildlife habitats, and

51. Photo of spray system

would require less use of treatment chemicals, but much greater commitments of land and energy resources.

52. Photo of Park area

Spray would make feasible open spaces and a wilderness park.

PHOTO:
53. Advisory group meeting with different advantages and disadvantages

It is not enough for an advisory group to simply identify the advantages or disadvantages of various alternatives because if the project is to succeed in the long run, it must be acceptable to the people.

54. News headlines

The advisory group should assist in developing a public participation program such as informational meetings and media publicity that reaches all elements in the community.

55. Field photo: Stream

56. Wildlife photo: Bird

57. Wildlife photo: Deer

	Music
(Graphic) 58. Plan selection	The selection of the alternative plan that is best suited to a community's water quality goals is the main purpose of facilities planning,
59. Cost-effectiveness analysis	and cost-effectiveness analysis provides the basis for this decision.
60. Sample of accounts sheet	All significant costs and effects of each alternative must be clearly displayed. Costs and effects can be displayed in various formats, although an approach suggested by EPA is an accounts sheet.
61. Pennypack accounts matrix	As shown by the matrix for the Pennypack, these accounts can be quite lengthy. It is not always easy to see relationships among the various items.
Photos: 62. Woman at meeting	But <u>individuals</u> do not have to deal with these costs and effects <u>alone</u>, that's why there is an advisory <u>group</u>, to help each other. . .
63. Advisory group photos	. . . to, as a group, assist in identifying tradeoffs, especially the composite effects of alternatives --and to evaluate all factors together.
64.	
65.	
66.	
67.	
68.	
69. Pennypack acknowledgement	Credit slide
70. Produced by The Pennsylvania State University, The Capitol Campus, under a grant provided by U.S. Environemental Protection Agency	Credit slide

END

*U S GOVERNMENT PRINTING OFFICE: 1980 341-082/113

Working for Clean Water is a program designed to help advisory groups improve decision making in water quality planning. It aims at helping people focus on essential issues and questions, by providing trained instructors and materials suitable for persons with non-technical backgrounds. These materials include a citizen handbook on important principles and considerations about topics in water quality planning, an audiovisual presentation, and instructor guide for elaborating points, providing additional information, and engaging in problem-solving exercises.

This program consists of 18 informational units on various aspects of water quality planning:

- Role of Advisory Groups
- Public Participation
- Nonpoint Source Pollution: Agriculture, Forestry, and Mining
- Urban Stormwater Runoff
- Groundwater Contamination
- Facility Planning in the Construction Grants Program
- Municipal Wastewater Processes: Overview
- Municipal Wastewater Processes: Details
- Small Systems
- Innovative and Alternative Technologies
- Industrial Pretreatment
- Land Treatment
- Water Conservation and Reuse
- Multiple Use
- Environmental Assessment
- Cost-Effectiveness Analysis
- Wastewater Facilities Operation and Maintenance
- Financial Management

The units are not designed to make technical experts out of citizens and local officials. Each unit contains essential facts, key questions, advice on how to deal with the issues, and clearly-written technical backgrounds. In short, each unit provides the information that citizen advisors need to better fulfill their role.

This program is available through public participation coordinators at the regional offices of the United States Environmental Protection Agency.